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Climate Change Impact on Rainfall for Heran river basin in Lower Narmada River Basin, Gujarat, India

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Abstract*— This paper reviews the impact of climate change on rainfall in a river basin. The impacts are assessed on annual rainfall as wells as on monthly rainfall by identifying their trend. Three statistical methods i.e. Regression analysis, Man- Kendall test an Innovative trend analysis have been used to identify the trend of annual and monthly rainfall in a Heran riven basin in the lower Narmada river basin. Also spatio-temproral distribution of the trend of annual and monthly rainfall have been developed. The study will be helpful for planning and management of the water resources in the basin

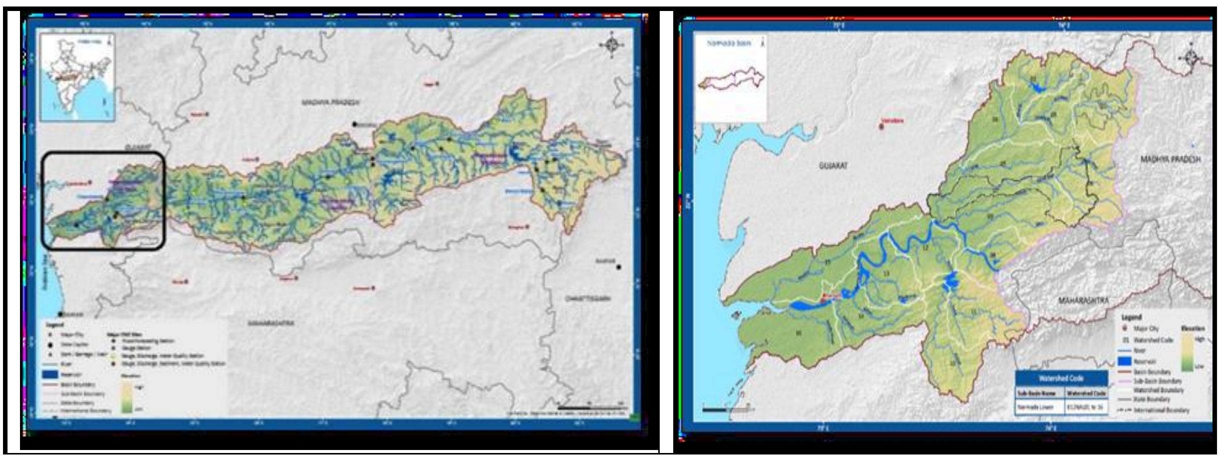
***Keywords*— Climate change, Annual and monthly Rainfall, Trend Analysis, River basin, Spatio-Temporal**

I. INTRODUCTION

Climate change is one of the most challenging issues facing by the world today, which is expected to have long term impacts on sustainable living. Strong spatio-temporal variations and large departures from its normal values are generally observed in Indian monsoon rainfall. Rainfall is the most important parameter in the hydrological cycle and it directly affects the volume of direct/surface runoff. This focusses on the need of examining the influence of climate change on rainfall variability and trend of the rainfall. The changes in the average temperature of the earth are now being evidently witnessed by the changes in the rainfall pattern and distribution, resulting in frequent floods and droughts with higher severities, intense precipitation. Three statistical methods i.e. Regression analysis, Man- Kendall test an Innovative trend analysis have been used to identify the trend of annual and monthly rainfall in a Heran riven basin in the lower Narmada river basin. Also spatio-temproral distribution of the trend of annual and monthly rainfall have been developed in the study area comprising of Heran river basin in lower Narmada sub-basin.

The Heran river is a tributary of Orsang, which itself forms a major river sub-basin of the lower Narmada valley. It rises in the hills of Jamla of Madhya Pradesh state at an elevation of 407 m and flows westerly with Orsang near Bhilodiya at an elevation of 40 m. Though most of the precipitation is received during monsoon season, it is a perennial river. The Heran river basin area is located in the eastern parts of the Mainland Gujarat and Southwestern part of Madhya Pradesh. Out of the total 1209 sq.km catchment, 748 sq.km is shared by the Vadodara district of Gujarat State and 461 sq.km is shared by the Jhabua district of Madhya Pradesh. The basin area lies between the N Latitudes 22° 05’ 00" and 22° 15’ 48” and E longitudes, 73° 30’ 00” and 74° 15' 20”. It comprises major parts of Chhotaudepur and Sankheda talukas and small portion of Jamougam, Naswadi, Tilakwada and Dabhoi talukas of Vadodara district.

The mean maximum and minimum temperatures experienced during the year range between 34°C and 19°C respectively. The basin shows dominantly a dendritic to trellis pattern. Fig. 1 shows basin map of the Narmada river basin, basin map of Narmada lower sub-basin, and the study area- Heran river basin with the locations of raingauging stations- Kawant, Lalpur and Rampura ; rivergauging station- Wasna and weather stations- Chalamali and Chandod.



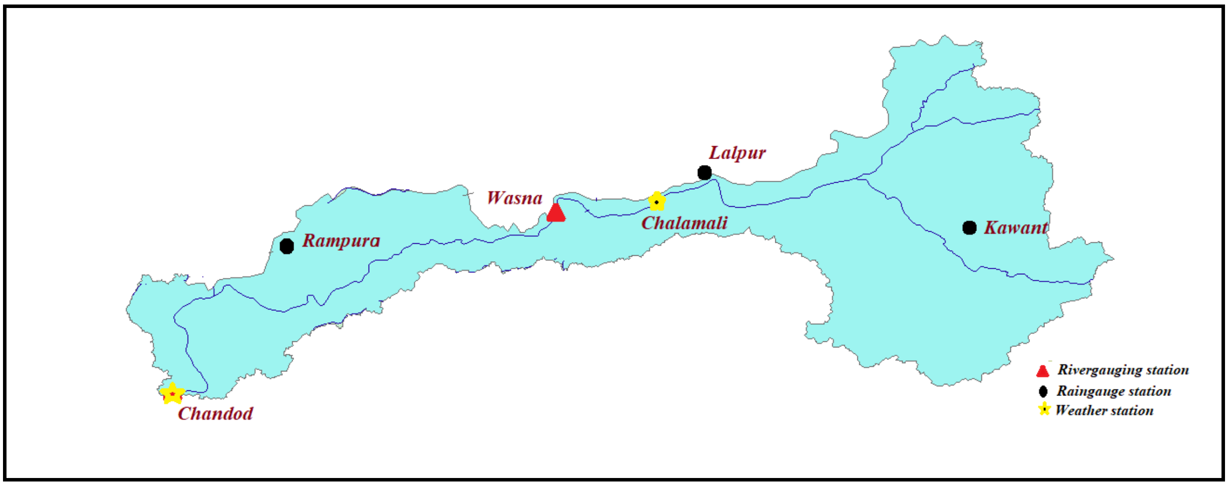


Fig. 1 Heran river basin and its location in the Lower Narmada river basin

Many researchers have investigated the climate change impacts on rainfall, temperature change, etc. Oza and Kishtawal (2014) showed that declining rainfall has an adverse effect on water resources, agricultural output and economy. It is well realized that natural climate variability (e.g. decadal changes in circulation) and human induced (e.g. land cover and emissions of greenhouse gases) changes alter the rainfall patterns. Reddy and Nathawat (2013) revealed that the water resources would come under increasing pressure in Indian subcontinent due to the changing climate. These changes will have profound effects on water requirement of Horticulture crops in India. The climate affects the demand for water as well as the supply and quality. Particularly, in arid and semi-arid regions of India nay shortfalls in water supply. Increase in the temperature is a global phenomenon and it influences or controls other elements of the weather, such as precipitation, humidity, clouds and atmospheric pressure. In India, studies by several authors have shown that there is increasing trend in surface temperature and no significant trend in rainfall and decreasing/increasing trends in rainfall (Oza and Kishtawal, 2014). Many research work on trend analysis of Indian summer monsoon, rainfall pattern, are carried out by Mondal, Kundu and Mukhopadhyay (2012); Onoz and Bayazit (2003); Lacombe and McCartney (2016); Kumar, Jain and Singh (2010); Oza and Kishtawal (2014); Bekele and Knapp (2010), Coulibaly et.al.(2018) using Mann Kendall Non- Parametric Test.

II. DATA ANALYSIS AND METHODS

This section comprises of methods to analyze the trend of the annual rainfall as well as the monthly rainfall for each month of the monsoon season (June to October). As shown in Fig. 1, there are three raingauging stations namely, Rampura, Lalpur and Kawant have been installed in the study area. The normal annual rainfall at stations Rampura, Lalpur and Kawant are found to be 999.14 mm, 929.24 mm and 724.82 mm respectively. These three stations in the study are found adequate as the optimum number of raingauge stations, even with 5% error in determining mean rainfall.
Three methods for the tracking the trend have been used in this study. Regression analysis, Mann- Kendall test with Sen's slope estimator and innovative trend analysis have been applied and discussed as below. n easy way to comply with the conference paper formatting requirements is to use this document as a template and simply type your text into it.

A. Regression analysis at Rampura station age Layout

Rampura station is located in the Dabhoi Tehsil of the Vadodara district. The daily rainfall data was available from 1972 to 2016 from State Water Data Centre (SWDC). The annual rainfall data series and the number of rainy days in a year at Rampura station are as shown in Fig. 2, which shows increasing trend for both

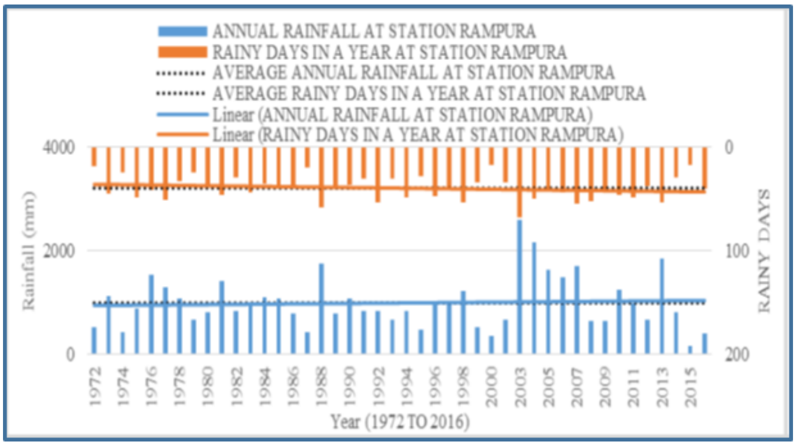


Fig. 1 Trend of Annual rainfall and number of rainy days in a year at Rampura station

Similarly, the trend analysis have been carried out for the annual as well as for monthly rainfall and number of rainy days in the months - June, July, August, September and October at Kawant and Lalpur station and trend increasing/decreasing is shown in Table 1.

TABLE I
TREND ANALYSIS FOR RAINFALL AND NUMBER OF RAINY DAYS AT FOUR RAINGAUGE STATIONS BY REGRESSION ANALYSIS

Station	**Month**	**Trend for rainfall**	**Trend for rainy days**
Kanwat (1964-2011)	June	Increasing	Decreasing
	July	No trend	Decreasing
	Aug	Increasing	Decreasing
	Sep	Decreasing	Increasing
	Annual	Increasing	Increasing
Lalpur (1981- 2016)	June	Decreasing	Decreasing
	July	Increasing	Decreasing
	Aug	No trend	Decreasing
	Sep	Increasing	Increasing
	Annual	Increasing	Decreasing
Rampura (1972 -2016)	June	Decreasing	Decreasing
	July	Increasing	Increasing
	Aug	Decreasing	Decreasing
	Sep	Increasing	Increasing
	Annual	Increasing	Increasing

It is seen from Table 1 that the annual rainfall shows increasing trend at all the stations in the basin. In the month of June, the rainfall shows reducing trend at two stations out of three stations. In the month of September the rainfall increases at two stations out of three stations.

B. Analysis of rainfall by Mann-Kendall Test

Non-parametric method formulated by Mann (1945) for trend detection and the test statistic have been given by Kendall (1975) for testing non-linear trend. The Mann-Kendall test statistic is computed.

$$S = \sum_{j=1}^{n-1} \sum_{j=1+i}^{n} \text{sgn}\,(x_j - x_i) \qquad 1$$

The application of trend test is done to a time series x_i that is ranked from i = 1,2,………n-1 and x_j which is ranked from j = i+1,2,……….n. Each of the data point x_i is taken as a reference point, it is compared with the rest of the data point x_j so that,

$$\text{sgn}(x_j - x_i) = \begin{cases} +1, > (x_j - x_i) \\ 0, = (x_j - x_i) \\ -1, < (x_j - x_i) \end{cases} \qquad 2$$

For $n \geq 8$, the statistic S is approximately normally distributed with the mean.
E(S) = 0, the variance statistic is given as

$$\text{Var}\,(S) = \frac{n(n-1)\,(2n+5) - \sum_{i=1}^{m} t_i\,(i)(i-1)(2i+5)}{18} \qquad 3$$

Where t_i is considered as the number of ties up to sample i. The test statistics Z_c is computed as

$$Z = \begin{cases} \frac{S-1}{\sqrt{\text{Var}(S)}}, S > 0 \\ 0, S = 0 \\ \frac{S+1}{\sqrt{\text{Var}(S)}}, S < 0 \end{cases} \qquad 4$$

Here statistic Z follows a standard normal distribution. A positive value of Z signifies an upward trend and vice versa. A significance level (α) is utilized for testing either an upward or downward monotone trend (two-tailed test). If Z seems greater than Zα/2, then the trend is considered as significant (Mondal et al., 2012). Compute p-value and check whether trends are statistically significant at 5% significance level (Shah et al., 2016).

The degree of trend is projected by the Sen's estimator. Here, the slope (Ti) of all data pairs is computed as (Sen, 1968) A positive value of β indicates an upward trend and vice versa (Shah et al., 2016).

$$\beta = \text{Median}\left(\frac{X_i - X_j}{i-j}\right) \quad \text{for } i = 1, 2, \ldots, N \qquad 5$$

where,
Ti = slope between data points Xi and Xj,
Xi = data measurement at time i
Xj = data measurement at time j
j = time after time i

TABLE 2
RESULTS OF MANN-KENDALL TEST AND SEN'S SLOPE ESTIMATOR FOR ANNUAL AND MONTHLY RAINFALL

Station	Number of years	Variable	Mann-Kendall Z - statistic	p - value	Kendall's S	Sen's slope (β) value	Mean	% change in magnitude of trend	Significance	Trend
Kawant (1964-2011)	44	June	1.77	1.92	176	1.453	118.18	104.50	Non-Significant	Increasing
		July	-0.11	0.91	-12	-0.263	276.93	-8.07	Non-Significant	Decreasing
		August	1.05	1.71	105	2.421	259.79	79.21	Non-Significant	Increasing
		September	0.38	1.30	39	0.344	104.43	28.00	Non-Significant	Increasing
		October	0.55	1.42	46	0	28.92	0.00	Non-Significant	Increasing
		Annual	1.11	1.73	107	7.431	724.82	87.14	Significant	Increasing
Lalpur (1981 -2015)	29	June	-0.98	0.33	-53	-1.547	106.81	-94.14	Non-Significant	Decreasing
		July	0.49	1.38	27	1.296	326.82	25.78	Non-Significant	Increasing
		August	-0.43	0.67	-24	-2.506	309.78	-52.58	Non-Significant	Decreasing
		September	1.59	1.89	86	5.469	193.32	183.88	Non-Significant	Increasing
		October	0.43	1.33	21	0	22.01	0.00	Non-Significant	Increasing
		Annual	0.09	1.07	6	0.808	929.24	5.65	Non-Significant	Increasing
Rampura (1972-2016)	44	June	-1.73	0.08	-172	-1.586	110.35	-67.55	Non-Significant	Decreasing
		July	0.46	1.35	46	1.115	355.16	14.76	Non-Significant	Increasing
		August	-0.54	0.59	-53	-1.552	353.62	-20.63	Significant	Decreasing
		September	1.75	1.92	174	2.171	184.00	55.45	Non-Significant	Increasing
		October	-0.36	0.72	-25	0	30.39	0.00	Non-Significant	Decreasing
		Annual	-0.48	0.63	-48	-1.493	999.14	-7.02	Non-Significant	Decreasing

It seen from Table 2 that the annual rainfall increases at two stations out of three stations. In the month of June, the rainfall reduces at two stations. In the month of September the rainfall shows increasing trend at all three stations.

C. Innovative Trend Analysis

This methodology is considering the 1:1 (45°) straight line on the Cartesian coordinate system for detecting the trend. In this method, a recorded hydrological data is divided into two equal halves from the first data to the end data, and both series are independently sorted in ascending manner. The first series (Xi) located on X-axis, and the other series (Yj) located on Y-axis based on the Cartesian coordinate system (Ay and Ozgur, 2015). If data collected on the 1:1 (45˚) straight line, it could be said that there is no trend. If data are in the upper triangular area of the 1:1 straight line, it could be said that there is an increasing trend, If data lied in the below triangular area of the 1:1 straight line, it could be said that there is a decreasing trend in time series. This method also enables detection of trends in different hydrologic regimes like low, medium and high. The Innovative trend analysis have been carried out for annual and monthly rainfall at the raingauging stations in a river basin. The results of innovative trend analysis are as shown below.
Fig. 3, Fig. 4 and Fig. 5 shows the innovative trend analysis plots for Kawant, Lalpur, Rampura stations respectively for annual and monthly rainfall.``

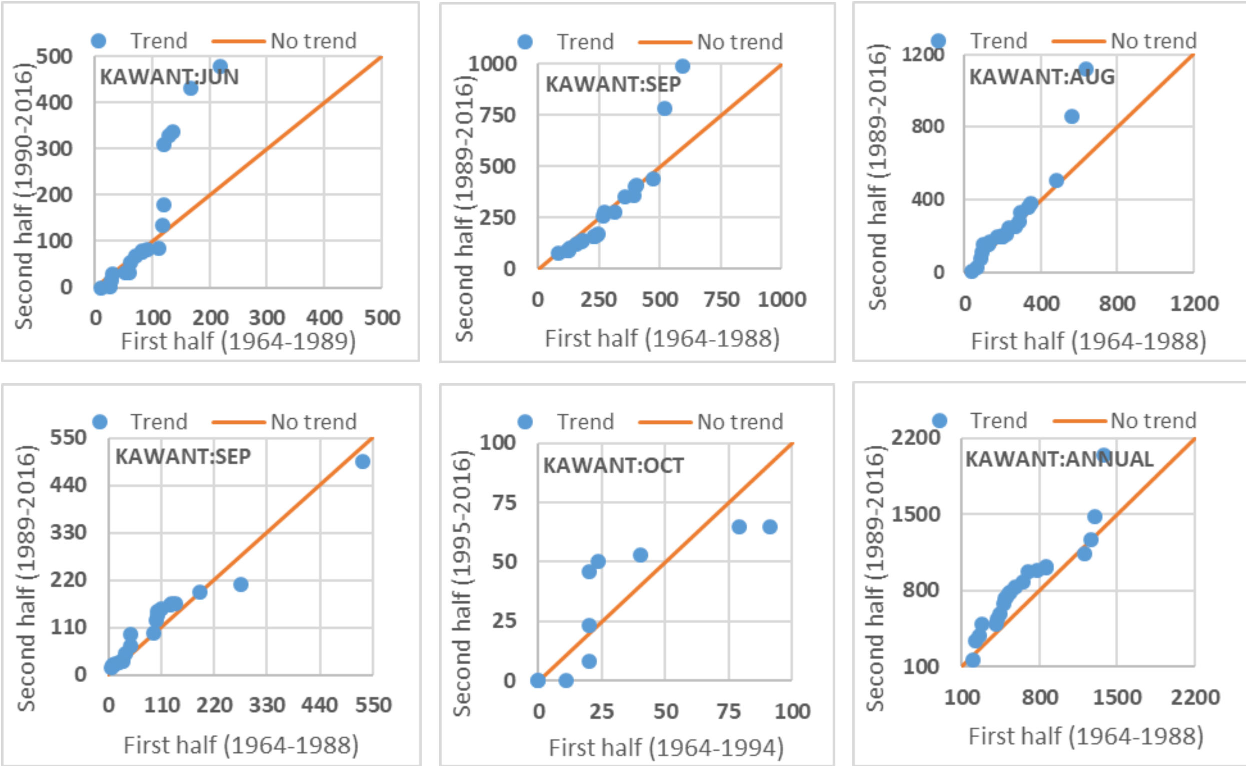


Fig. 3 Innovative trend analysis for Kanwat raingauging station for monthly and annual rainfall

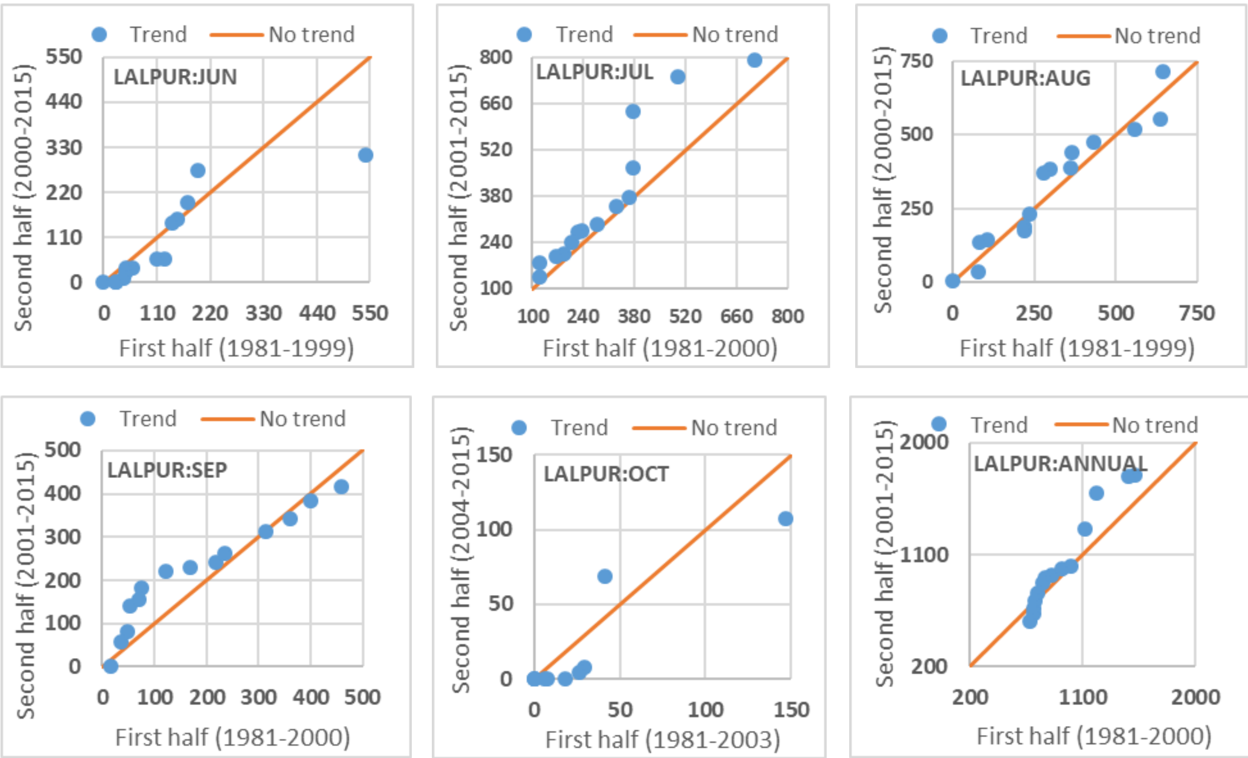


Fig. 4 Innovative trend analysis for Lalpur raingauging station for monthly and annual rainfall

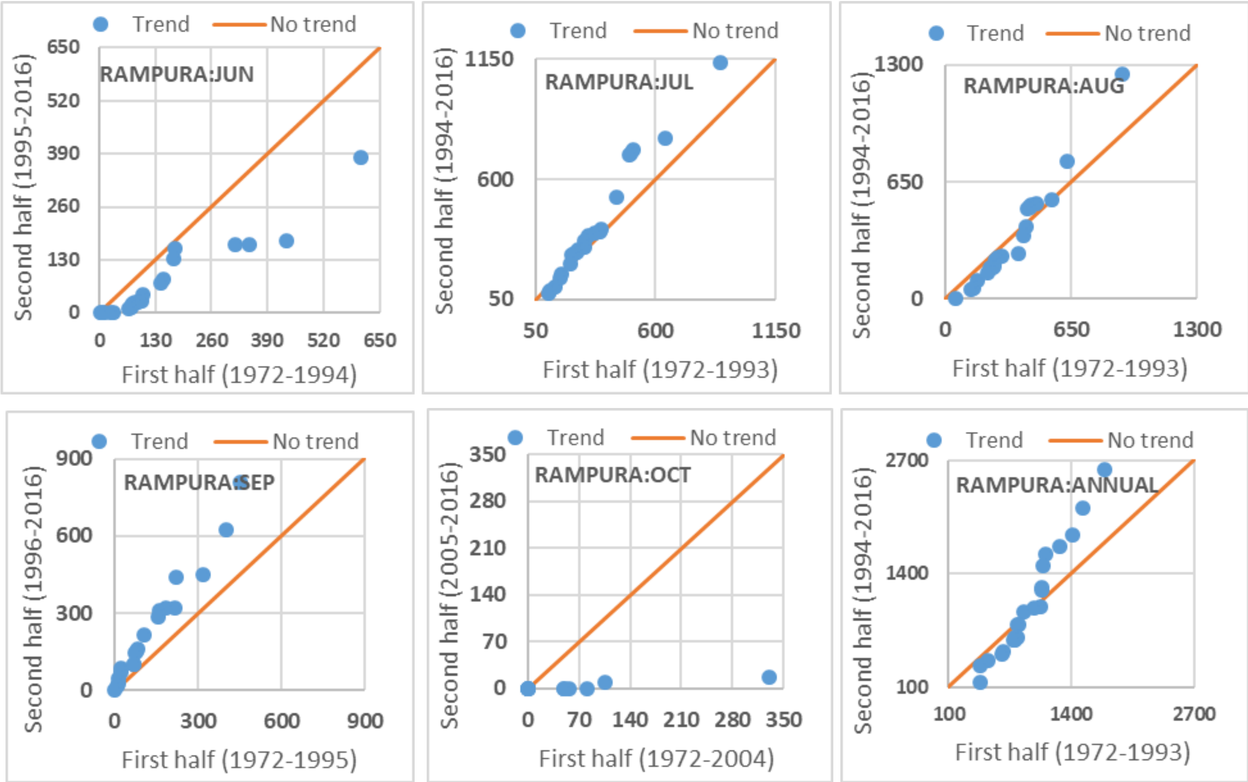


Fig. 5 Innovative trend analysis for Rampura raingauging station for monthly and annual rainfall

It can be seen from Fig. 3, Fig. 4 and Fig. 5 that annual rainfall shows increasing trend at Kanwant and Lalpur stations and shows increasing trend for high rainfall values at Rampura raingauge station. At all three stations innovative tend analysis shows increasing trend in September month.

Right = 19mm (0.75")

III. SPATIAL DISTRIBUTION OF ANNUAL AND MONTHLY RAINFALL AND SEN'S SLOPE AGE STYLE

The spatial distribution of annual and monthly rainfall and its trend represented by sen's slope is necessary to represent the geographical variation of temporal trend of annual and monthly rainfall. Fig. 6 and Fig. 7 shows spatial distribution of annual and monthly rainfall in Heran river basin.

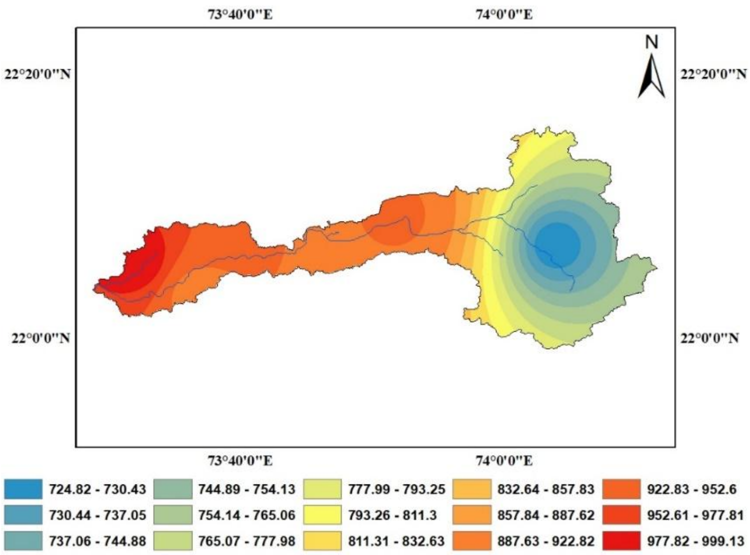


Fig. 6 Spatial distribution of annual rainfall in a Heran river basin

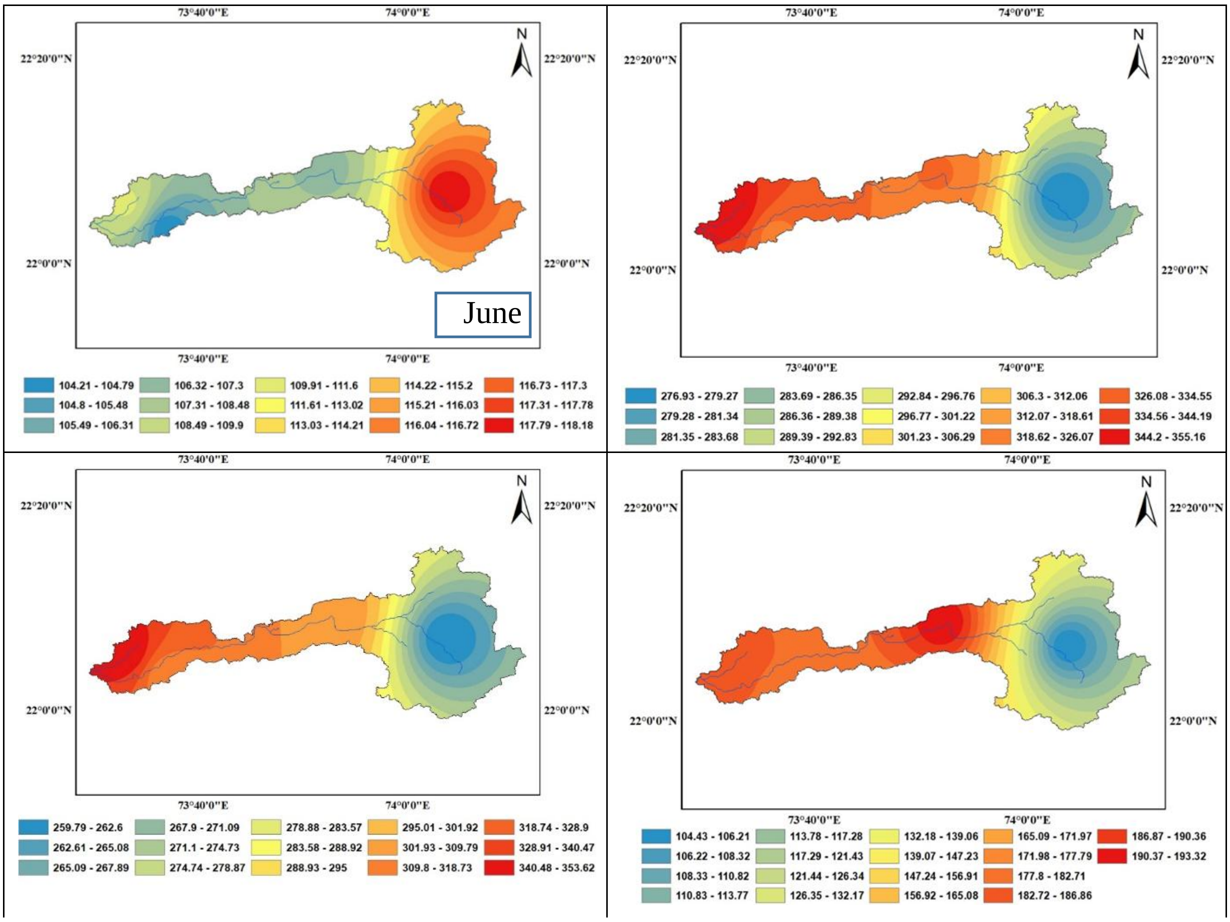


Fig .7 Spatial distribution of monthly rainfall in a Heran river basin

It can be seen from Fig. 6 and Fig. 7 that annual rainfall at lowest at Kawant raingauge station and lowest at Rampura raingauging station. Also, the similar distribution is prevailing in the month of July, August and September. While, in the month of June the rainfall distribution over the basin is not identical to the annual rainfall distribution.

Fig. 8 and Fig. 9 shows spatial distribution of sen's slope monthly and annual rainfall for trend detection respectively.

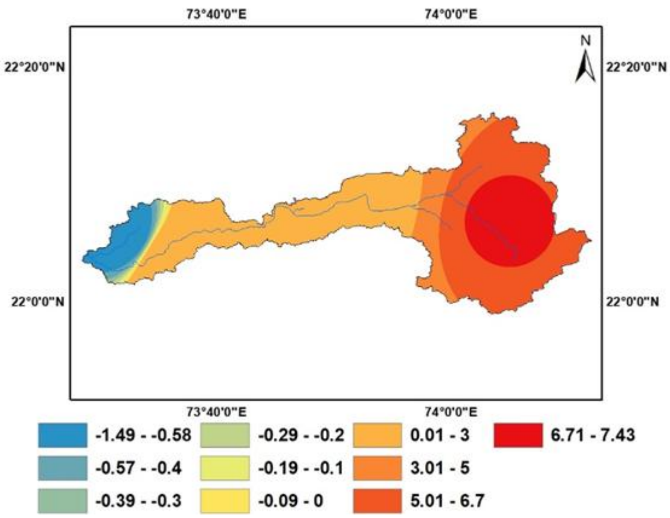


Fig. 8 Spatial distribution of sen's slope of annual rainfall

It is seen from Figure 8 that the sen's slope detecting the maximum and positive trend in almost entire basin except the lower region the basin.

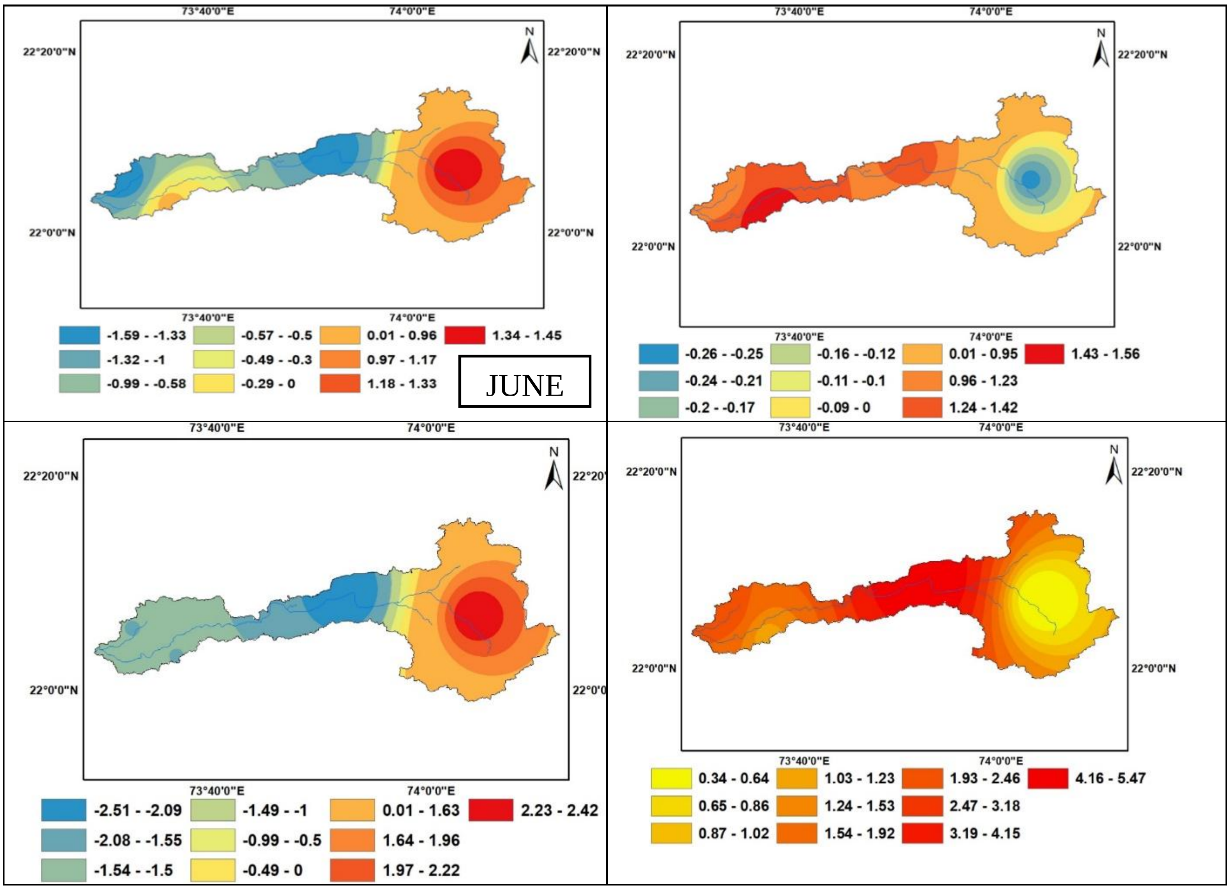


Fig. 9 shows the spatial distribution of sen's of monthly rainfall

It is seen from Fig. 9 that June month shows negative (reducing trend) within almost the entire river basin except upper region around Kanwant in the basin. July month shows increasing trend within the entire river basin except some region around. Kanwant. September month shows positive trend within the entire river basin.

IV. Conclusions

The objective of this study is to investigate the regional impact of climate change on Heran river basin in Narmada lower sub-basin.

From the results obtained in this study, it is concluded for the study area that the climate change impacts on the small-regional scale study area confirms the increasing trend in the rainfall magnitude and number of rainy days in a year, decreasing trend in monthly rainfall and rainy days in the month of June increasing trend in monthly rainfall magnitude in the month of September month.

It is observed that the results of trend identification from Regression analysis, M – K statistical test and Innovative trend analysis closely agreeing.

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